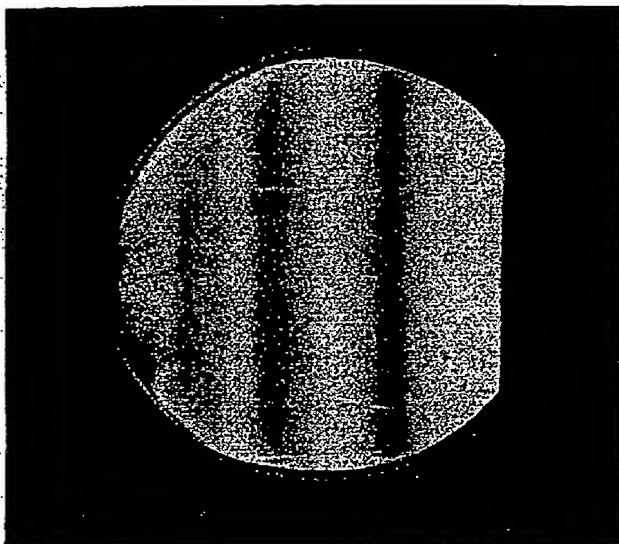Interference colors in the light reflected from a thin soap film.

UNIVERSITY PHYSICS

COMPLETE EDITION

by

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Table 28-1, the resistivity of copper is 1.72×10^{-8} ohm·m. Therefore,

$$E = \frac{1.72 \times 10^{-8} \text{ ohm·m} \times 200 \text{ amp}}{10^{-4} \text{ m}^2}$$

$$= 0.0344 \text{ volt/m.}$$

Since the electric intensity or potential gradient is 0.0344 volt/m, the potential difference between two points 100 m apart is

$$V_a - V_b = 0.0344 \text{ volt/m} \times 100 \text{ m} = 3.44 \text{ volts.}$$

EXAMPLE 2. What is the potential difference between two points on the above 0 m apart?

The more common method of solution would be to first compute the resistance of the wire from $R = \rho L/A$ and then find the potential difference from Ri. We have

$$R = \frac{1.72 \times 10^{-8} \text{ ohm·m} \times 100 \text{ m}}{10^{-6} \text{ m}^2} = 0.0172 \text{ ohm.}$$

$$V_{ab} = 0.0172 \text{ ohm} \times 200 \text{ amp} = 3.44 \text{ volts,}$$

is the same as the previous answer.

3 Measurement of current, potential difference, and resistance. Instruments are measured by instruments called *galvanometers* or *ammeters*. The most common type makes use of the interaction between a current-carrying conductor and a magnetic field and is described in Chapter 32. For present purposes it is sufficient to know that such instruments measure the current at a point such as a, b, or c in Fig. 28-8(a), so the circuit must be opened and the ammeter inserted at that point so as for the current to be measured passes *through* the ammeter, as in Fig. 28-8(a). An ammeter is a *low resistance instrument*, representative being a few hundredths or thousandths of an ohm.

The potential difference between two points of a circuit might be measured with an electroscope or electrometer. It is more convenient, however, to use some type of *voltmeter*, the construction of which is described more fully in Chapter 32. Most voltmeters, unlike electroscopes and electrometers, are current operated. The voltmeter terminals are connected to the points between which the potential difference is to be measured. Figure 28-8(b) shows a voltmeter V connected so as to measure potential difference between the terminals of the cell. If the voltmeter terminals are disregarded, a voltmeter may be treated as of its construction are disregarded, a voltmeter may be treated as being a high resistance, and automatically indicates the potential difference between terminals. Typical resistances, for a 100-volt instrument, are from 100 to 100,000 ohms.
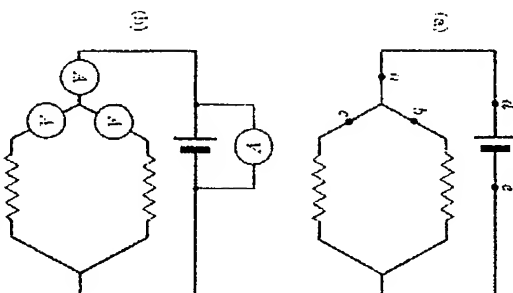
Fig. 28-8. Ammeter and voltmeter connections.

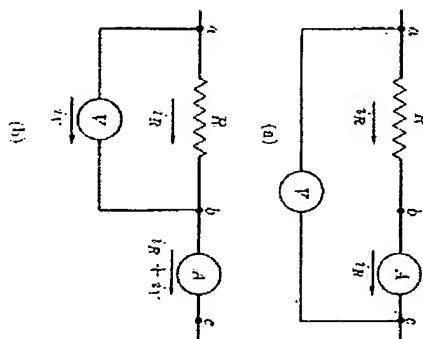The resistance of a conductor is the ratio of the potential difference between its terminals to the current in it. The most straightforward method of measuring resistance is therefore to measure these two quantities and divide one by the other. The ammeter-voltmeter method for so doing is illustrated in Fig. 28-9. In circuit (a) the ammeter measures the current i_R in the resistor, but the voltmeter reads V_a, and not the potential difference V_{ab} between the terminals of the resistor. In circuit (b) the voltmeter reads V_{ab}, but the ammeter reads the *sum* of the currents in the resistor and in the voltmeter. Hence, whichever circuit is used, corrections must be made to the reading of one meter or the other, unless these corrections can be shown to be negligible.

Fig. 28-9. Ammeter-voltmeter methods of measuring resistance.

28-7 The Wheatstone bridge. The Wheatstone bridge circuit, shown in Fig. 28-10, is widely used for the rapid and precise measurement of resistance. It was invented in 1843 by the English scientist, Charles Wheatstone. M, N, and P are adjustable resistors which have been previously calibrated, and X represents the unknown resistance. To use the bridge, switches K_1 and K_2 are closed and the resistance of P is adjusted until the galvanometer G shows no deflection. Points b and c must then be at the same potential or, in other words, the potential drop from a to b equals that from a to c. Also, the drop from b to d equals that from c to d. Since the galvanometer current is zero, the current in M equals
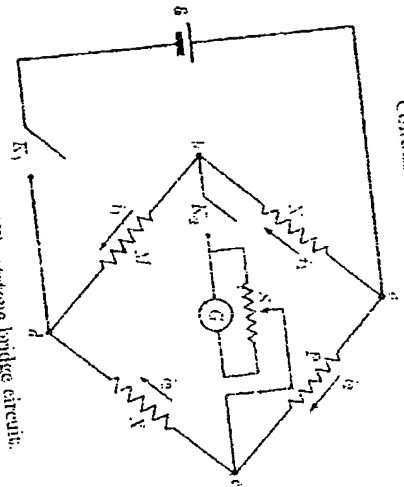
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CURRENT AND RESISTANCE [Chap. 28

Fig. 28-10. Wheatstone bridge circuit.

that in N, say i_1, and the current in P equals that in X, say i_2. Then, since $V_{ab} = V_{ac}$, it follows that

$$i_1 N = i_2 X.$$

and since $V_{bd} = V_{cd}$,

$$i_1 M = i_2 P.$$

When the second equation is divided by the first, we find

$$X = \frac{M}{N} P.$$

Hence if M, N, and P are known, X can be computed. The ratio M/N is usually set at some integral power of 10, such as .01, 1, 100, etc., for simplicity in computation.

During preliminary adjustments, when the bridge may be far from balance and V_{br} large, the galvanometer must be protected with that of the galvanometer terminals. When a resistor whose resistance is large compared with that of the galvanometer terminals. When a resistor whose resistance is large compared across the galvanometer terminals. When a resistor whose resistance is large compared across the galvanometer, none of the current A resistor whose resistance is large compared across the galvanometer terminals. When eter is permanently connected across the galvanometer terminals. In a position such that shown, that portion of the resistor at the left of the contact, and this combination sliding contact is in series with the galvanometer, and this portion of the resistor at the right of the in the path between b and c passes through the galvanometer. In a position such that shown, that portion of the resistor at the left of the contact. Hence the sliding contact is at the left end of the resistor, none of the current passes through only a fraction of the current passes through the galvanometer. The is shunted by that portion of the current at the left of the contact. With the sliding contact is in series with the resistor, all of the current passes through only a fraction of the current passes through the resistor is at the left the galvanometer except the small fraction by-passed by the resistor. The sliding contact at the right of the resistor, all of the current passes through only a fraction of the current by-passed when the contact is at the left galvanometer is, therefore fully protected when the contact is at the left end of the resistor and practically full galvanometer sensitivity is attained when the contact is at the right end.
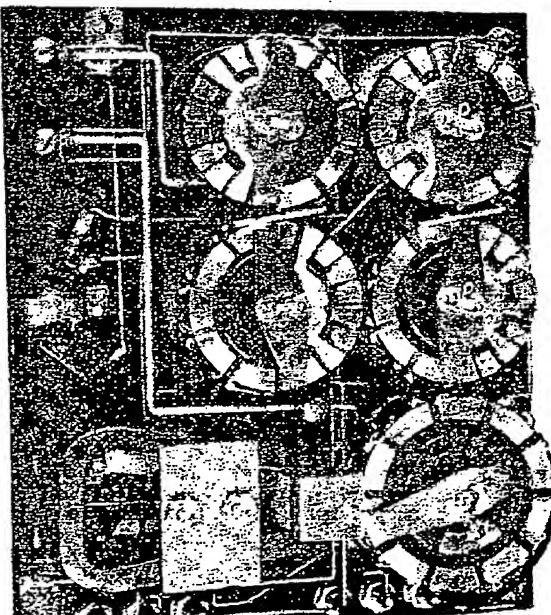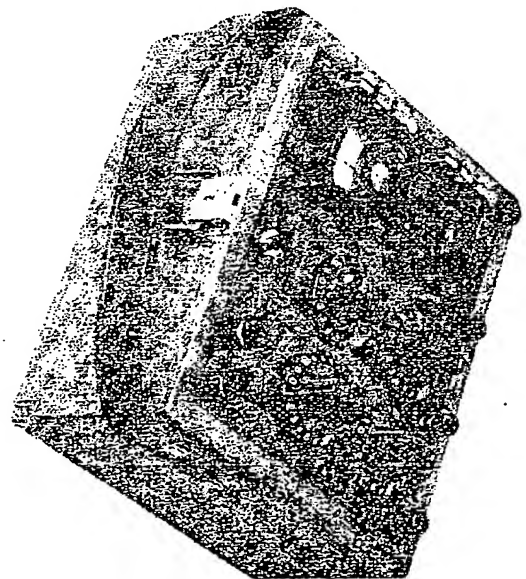
28-7]

THE WHEATSTONE BRIDGE

Fig. 28-11. Portable Wheatstone bridge. (Courtesy of Leeds and Nor